HELIOS I ENERGETIC PARTICLE OBSERVATIONS OF THE SOLAR GAMMA RAY FLARE EVENTS OF 7, 21 JUNE 1980 and 3 JUNE 1982

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ABSTRACT

The observed characteristics of the energetic particles associated with the solar γ-ray events of 3, 21 June 1980 and 3 June 1982 differ in several important aspects from the typical solar particle increases. They have flat energy spectra, are electron rich and have small precursor increases that begin some hours before the impulsive flare increase.

1. Introduction. Solar flare γ-rays and neutrons provide a direct means of determining the flux and energy spectra of those energetic particles accelerated by the flares which impact the lower coronae and photosphere (Ramaty et al., 1982, 1983; Chupp, 1984). The γ-ray time histories, when compared to those of x-rays, establish limits on the time required for particle acceleration. The flux and energy spectra of those flare accelerated particles which escape from the Sun can be determined by interplanetary observations. Comparing these two complimentary particle populations provides further understanding of the particle acceleration and transport processes in the flare region.

The Solar Maximum Mission Gamma Ray experiment of Chupp and his co-workers have made detailed observations of a number of solar γ-ray events (cf Chupp, 1984). Three of these flare increases are of special importance: 3 June 1982 and 21 June 1980 which are large intense γ-ray events that also produced a detectable flux of solar neutrons at 1 AU (Chupp et al., 1982, 1983); the 7 June 1980 event was more moderate in size, was accompanied by a small Hα flare, but the near simultaniety of the onset of γ-ray and soft x-ray emission implies that the particles are accelerated on a time scale of less than 2 seconds.

The Helios I spacecraft was in a favorable location at the time of each of these flares (Table 1). The small heliocentric distance

TABLE 1

SOLAR EVENT	FLARE LOCATION & Hα CLASS	PEAK TIME FLARE IMPULSIVE PHASE (1)	HELIOS I HELIOCENTRIC DISTANCE	HELIOLONGITUDE SEPARATION (2)	PROTON SPECTRAL INDEX γ	ELECTRON/PROTON	Fe/O	He/H	^{3}He/He^4
3 June 1982	S09 E72 2B	1143 5	0 57 AU	3°	1 2 (3-200 MeV)	1 (3-6 MeV)	2 5± 5	132	02± 014
21 June 1980	N19 W88 1B	0118	0 54 AU	33°	2 6 (8-200 MeV)	0 25 (3-6 MeV)	0 9± 02	29	03± 013
7 June 1982	N12 W74 1B	0312	0 37 AU	14°	2 3 (3-30 MeV)	0 7 (1-2 MeV)	NOT OBSERVED	4	< 02

(1) Earth Observed Time
(2) Heliolongitude Separation Between Helios I and Nominal Field Line (Based on measured plasma velocity) Connecting to the Region of the Flare Site

between the spacecraft and the flare site significantly enhances the observations of the source region characteristics. The detailed observations of the energetic particles associated with these γ-ray flare events by the Goddard cosmic ray experiment on Helios I are presented in the following discussion along with their implication for the acceleration process. This present study builds on the previous reports based on both ISEE-3 and Helios I energetic particle data (Evenson, et al., 1980; Pesses et.al.,1979; von Rosenvinge et al., 1981; McDonald and Van Hollebeke, 1985).

2. Helios-I Energetic Particle Observations. Both the 3 June 1982 and 21 June 1980 proton and electron data exhibit a "classical form" with a rapid rise to peak intensity followed by a relatively smooth exponential decay (Fig. 1). The peak fluxes at 50 MeV of 10.5 and 0.3 MeV protons mark these as moderate sized increases. For both events there is a definite precursor increase that begins some 3 hours before the major flare (McDonald and Van Hollebeke, 1985).

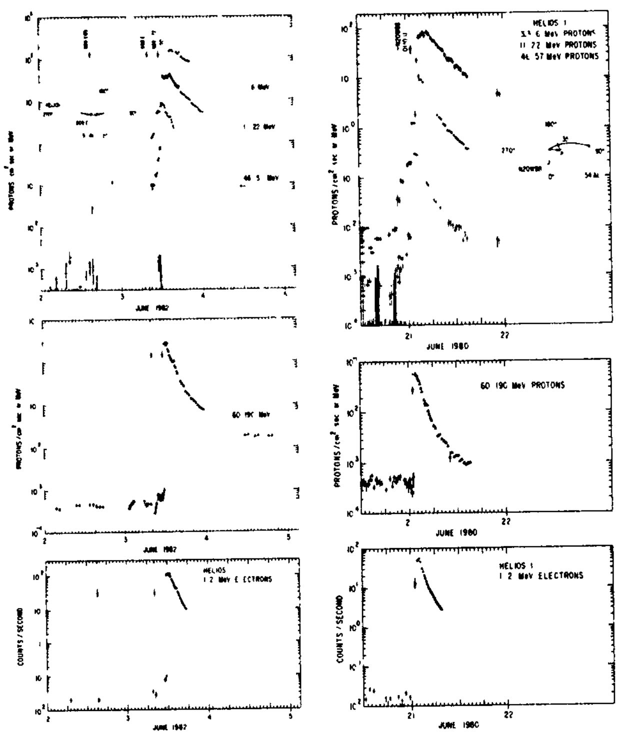

Fig.1 Energetic particle time histories. Vertical lines with arrows represent flare on-set times. The top insert shows the separation between Helios 1 and the nominal field line connecting to the flare site based on the measured plasma velocity.

The time history of the 7 June 1980 event is remarkably different from those of the other two increases (Fig 2). The solar energetic particle time histories are complex and the peak intensities are small (Fig. 2). The 1-2 MeV electrons arrive promptly at $\sim$0307 (Helios time), have a step increase at $\sim$0400 and there is a new injection at $\sim$0715. The integral electron channel for electrons > 250 keV is a single parameter measurement which also responds to x-rays and γ-rays. The time history of these electrons indicate flare activity at $\sim$ 0120, 0307 and 0715. The dashed line at 0300 (Helios time) is before the onset of the Hα flare producing the gamma-rays observed by SMM. The 1.25-6 and 3.7-21 MeV proton channels both show a precursor event in progress at the time of the flare (Fig. 2a, 2b). Unlike the MeV electrons, the onset time for protons appears to be delayed until $\sim$0400 (the transit time is $\sim$17 minutes for 15 MeV protons and 31 minutes for 3.6 MeV protons). The sharp decrease that occurs in all proton channels between 0400 and 0500 appears to be produced by a change in declination of the interplanetary magnetic field of $\sim$22°. The proton anisotropies from

3-20 MeV and 6-20 MeV are remarkably high from 0300-0900 so the observed proton intensities are very sensitive to the field direction. Fortunately the IP magnetic activity is usually quiet for this period and the field is in the plane normal to the spacecraft spin axis except for this deviation. There is also a new injection of 1.2-20 MeV protons at ∿0720.

These three γ-ray events (Table 1) have flat-energy spectra, are electron rich, have high Fe/O ratios, no clear pattern for H/He but two contain modest amounts of ^{3}He. Previous studies have shown that a significant fraction of the accelerated ions are confined at the flare site and have noted the high e/P ratio (Evenson et al., 1979, 1983; von Rosenvinge et al., 1979; Pesses et al., 1979; McDonald and Van Hollebeke, 1985). All three events are preceded by precursors some hours before the main event. In general, these precursor events would not have been observable at 1 AU.

3. Discussion. For the 3 June 1982 event the precursor can be identified with a flare in the same active region producing the primary event and extended to energies > 60 MeV as well as MeV electrons. The time history for the precursor event is very different from that observed in the impulsive phase of the main event. Since the particle intensity and anisotropy are still increasing at the onset of the large flare and in view of the short transit time of the 1.5 MeV electrons, it is unlikely that there were significant changes in the interplanetary propagation conditions between the precursor event and the large event at 11:34. The slow continuing increase in energetic particles between 8:40 and 11:30 must reflect the effects of leakage from a coronal source region. For the June 21, 1980 event, the time history or the precursor proton increase is remarkably similar to that of 3 June 1982. The 7 June preflare increase resembles a pulse-like injection feature.

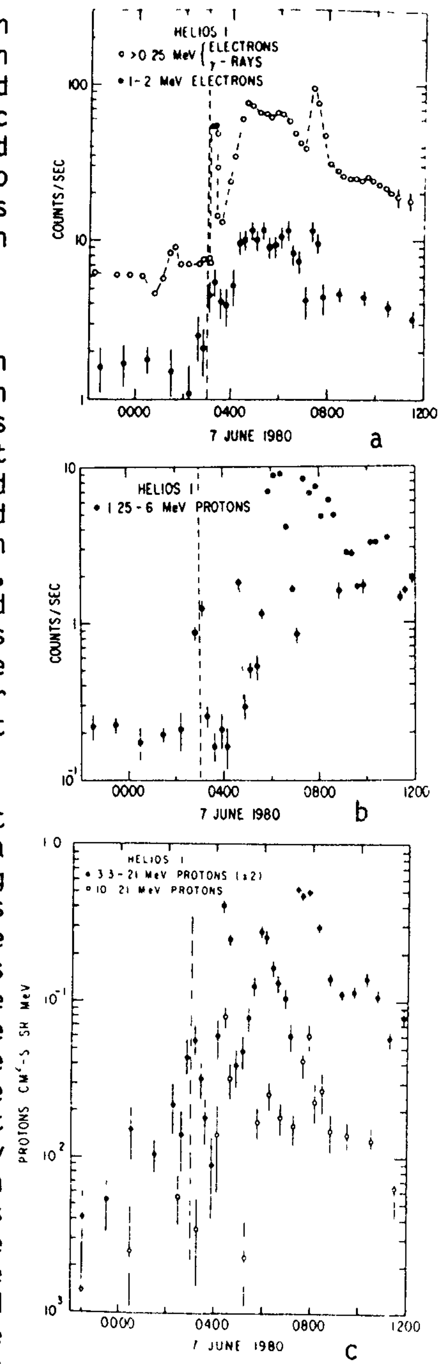

Fig.2 Energetic particle time histories for 7 June 1980 events. The DASHED line represents the flare on-set time

The precursor events described here imply that MeV ions (with energies extending to above 60 MeV along with MeV electrons in one case) are present in the corona prior to the onset of the main flare.

The presence of these energetic particles allows the consideration of models where the impulsive phase and the resulting shock both further accelerate and precipitate this existing reservoir of stored energetic particles. The possibility of a continual acceleration process over the 3 hrs. prior to the main flare cannot be ruled out.

The problem of the storage of ions in magnetic loops has been examined by Zweibel and Haber (1983). They found that particles with small pitch angles at the top of the loop, i.e., particles that mirror closer to the photosphere, will be lost much more rapidly. Using their calculations, it is found that an average electron density, $n_e < 10^8$ cm^{-3} is required if 5 MeV protons, mirroring near the top of the loop, are to lose < 2 MeV in 2 hr. On this time scale, particle drifts become important but may be reduced by twisting the loop. The shock acceleration of these particles in a closed loop structure will preferentially increase the velocity component along the field line and lead to enhanced particle precipitation.

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